AI in HEALTHCARE

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BUILDING THE FOUNDATION

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VOL. 2, NO. 1 2019

WELCOME

BUILDING FOUNDATIONS TO BUILD BETTER CARE

Matt Burr, VP and GM, Pure Storage's FlashBlade Business Unit

It's all about the data. We've been saying this for years. We can choose to look at this in one of two ways. It's either a constant truism or it actually evolves and gains mass over time. In the age of artificial intelligence, it is both.

In the last issue of this magazine, one small subhead offered great truth: "Don't let data access derail clinical breakthroughs." We can't, and thus need to build a solid strategy so that can't happen.

Healthcare is on a mission to innovate, powered by artificial intelligence and machine learning. Collecting data, storing data, learning from data—and even more so, grabbing a rear-view mirror to peer back into data to see what may have been missed. And doing that again and again over time. The value of data are now, *and* later, and thus always need to be nearby. That is what physicians, data scientists, engineers and informaticists need to generate breakthroughs and good outcomes on a daily basis.

The way forward is supported by smarter infrastructure that evolves along with data needs. At its core is a data hub with high computing power and a massively parallel structure, storing and serving up data quickly. We call this storage technology FlashBlade but this is why it matters. It offers a much higher rate of access from a much larger pool of data. In moving from rotational spinning disk to flash, enterprises are no longer bound to the latency principles of spinning disk or the throughput limitations of traditional disk systems. Hospitals, health systems and AI developers already using it are succeeding in accelerating and achieving innovation. To put it more simply: Storage got better, compute got faster, and now physicians and researchers are going deeper into these massive data stores to find more robust results.

Let's look at this from the perspective of a pediatric radiologist. Their numbers are low but the need for their skills is high. So there would be great benefit to developing a machine learning application, for example, that looks at 100,000 scans to detect anomalies—significantly greater than a person could ever accomplish—and identify 421 with anomalies that need to be viewed by a human. This would be significant, and accomplished in seconds.

That's an example of why we started Pure. We had a belief that if you took out the limitations of spinning disk and moved to an all-flash world, you would improve performance, density and speed. A smaller form factor also allows users to have more systems and increase performance by an order of magnitude. As we said, we can't let data access derail clinical breakthroughs.

Simplicity also was a mission. Modernizing storage needs to remove the complexity. To that end, our method of storage can be run by an IT generalist, rather than a storage professional. We also sought to create a non-disruptive model so systems are upgraded in real time. Some 60 to 70 percent of support incident triage is done proactively and invisibly to users.

This model also changes purchasing by eliminating the storage refresh and re-buy process. Costs are lower too. Since we are more efficient in how we're processing data and cost per terabyte or gigabyte, we hope to that fewer dollars spent on storage but put toward raises for staff or more investment in researchers.

We believe we have truly built something that is going to empower our customers to make the world better. This model offers a better method of storage, networking and compute. These three things were the legs of the stool that became the platform on which we built the company. And that's why Pure is behind this magazine and educational effort. We recognize the power of working alongside pioneers in AI, both in healthcare and in industry. We have built a foundation to support AI so healthcare can build a better foundation too. AI

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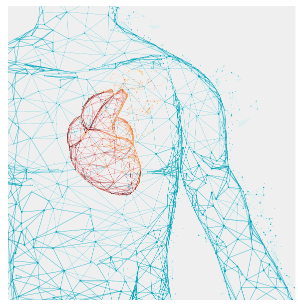

PLUS

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EMBRACING AI: WHY NOW IS THE TIME FOR MEDICAL IMAGING

by Mary C. Tierney, MS

Artificial and augmented intelligence are driving the future of medical imaging. Tectonic is the only way to describe the trend. And medical imaging is at the right place at the right time. Imaging stands to get better, stronger, faster and more efficient thanks to artificial intelligence, including machine learning, deep learning, convolutional neural networks and natural language processing. So why is medical imaging ripe for AI? Check out the opportunities and hear what experts have to say—and see what you should be doing now if you haven't already started.

Let's put the ridiculous aside. Radiologists will be empowered by AI, not replaced by it. Radiology has bought into the now-famous quote from Curtis Langlotz, MD, PhD, professor of radiology and biomedical informatics and director of the Center for Artificial Intelligence in Medicine and Imaging (AIMI Center) at Stanford University: "Artificial intelligence will not replace radiologists … but radiologists who use AI will replace radiologists who don't." It's the rallying cry.

Medical imaging's present and future is human *plus* machine. Radiologists are intrigued with AI's potential to expedite and improve their ability to interpret images. Some are starting to benefit from AI apps (see chart), and test plenty more of their own and commercial apps in development. Like many other industries, healthcare looks to AI to quickly wring insights from data, making information more useful and actionable. Machines can't think, but they can learn. Radiology is learning how they will mold the future.

Now is the time to get onboard and embrace AI, says the president of radiology's leading professional association. "AI has the potential to enhance our profession and transform the practice of radiology worldwide," RSNA President Vijay Rao, MD, told those gathered in Chicago for the profession's largest stage at the 2018 annual meeting. "It will allow radiologists to spend more time on initiatives that will benefit both patients and physicians."

Job one is recreating and rebranding reading rooms into digital diagnostic data hubs delivering "total imaging care," says Rao, who is the chair of the department of radiology at Jefferson University Hospitals in Philadelphia. Radiologists must be present with patients, referrers and care decision-making.

"If you generate more useful data, you become a better consultant," agrees Gary Wendt, MD, MBA, enterprise director of medical imaging and vice chair of informatics at the University of Wisconsin School of Medicine and Public Health in Madison. "If you're actually giving more people more actionable data, you as a physician are a more valuable part of the care process." (See more perspective from Wisconsin on page 14.)

Rao sees the digital diagnostic data hub as a gathering place for clinical teams to meet or participate virtually through video conferencing to make decisions regarding patient care. Radiologists could someday rely on AI to aggregate current imaging findings with priors from other clinical departments and social determinants of health. Lab results, surgical or biopsy findings, health history, physical exams, patient demographics, patient genomics and risk factors also can be gathered and integrated into the overall clinical analysis.

"What's hiding in this data that we're not acting on, that we need to be doing right now to help our patients?" asks Brandon Fornwalt, MD, PhD, a radiologist and data scientist who serves as co-director of the Cardiac Imaging Technology Lab (CITL) within Geisinger's Department of Imaging Science and Innovation. Researchers and radiologists are on a mission to find out. (See more on page 18)

Richard Bruce, MD, a neuroradiologist and medical director of radiology informatics at Univeristy of Wisconsin School of Medicine and Public Health, offers another perspective. He says AI is not necessarily always about providing something completely new "but about how to simply bring attention to the things that are already there. How do we reduce the noise? How do we bring to the top all those related things … so we can paint the most compelling picture, story, of the patient."

Rao calls her vision the "total imaging care delivery model." Instead of the referring physician leading the charge for patient communication, the radiologist can take over all aspects of imaging care for patients, which includes communicating results to the patient. "AI and related technologies give us the exact tools we need to finally make this vision a reality," she says.

JUST WHAT THE DOCTOR ORDERED

At the dawn of AI in the 1950s, researchers sought to produce an intelligent system capable of passing the Turing test: Can a machine's intelligence be made indistinguishable from that of a human? We are getting there. The last 70 years have seen alternating cycles of hope and despair, but a decade ago that began to change. The trajectory has been steadily moving up since as AI

BUILDING A HEAD OF STEAM

Medical imaging is the hottest cluster for AI start-ups, with 32 as of December, and the highest volume of investor transactions, topping $500 million. AI for MI also has the greatest revenue and potential for growth. This is the word from McKinsey & Company as published in the *Journal of the American College of Radiology*.

Here's how the AI algorithms break down: Many are modality specific, with 22 percent of companies focused on CT and 13 percent each on MRI and mammography. "CT and mammography lend themselves most readily to AI because attenuation information can be used in the learning algorithms," the authors wrote. "Other modalities present challenges: the interpretation of multisequence images in MRI, the user variability in ultrasound, and 2D limitations in X-rays."

AI apps bring 3 key strengths:

- Helping specialists interpret studies more quickly
- Detecting abnormalities "not visible to the human eye"
- Contributing to cost reductions by preventing unnecessary readmissions and reducing wasteful imaging AI

MACHINE LEARNING 101

SIMPLIFYING IT ONE TERM AT A TIME

Machine learning is one of the hottest topics in radiology and all of healthcare, but reading the latest and greatest ML research can be difficult, even for experienced medical professionals. A new analysis written by a team at Northern Ireland's Belfast City Hospital and published in the *American Journal of Roentgenology* was written with that very problem in mind.

Here's a quick primer:

- **Cross Validation:** How a lot of ML algorithms generate various performance measures. When researchers begin work on their algorithm, they separate subjects into two groups: a training dataset and a testing dataset. The training dataset is used to create the algorithm, training it so that it can make predictions. The testing dataset is used as an initial test of the algorithm's accuracy. The program can compare them, see what's best, alter overall predictive capability and "improve the generalizability of the results," the authors wrote.
- **ROC Curve:** By "plotting the effect of different levels of sensitivity on specificity," researchers can help readers understand the performance of their algorithm. "Algorithms that perform better will have a higher sensitivity and specificity and thus the area under the plotted line will be greater than those that perform worse. The metric termed the 'area under the ROC curve' or 'AUROC' is commonly quoted and offers a quick way to compare algorithms."

continued on page 8

began to learn without having to be programmed. Today, both consumable data and computing power have increased by orders of magnitude, with more widespread affordability.

In AI, medical imaging sees opportunity amongst obstacles to improve access and quality, reduce cost, make the patient experience better—and don't forget the caregivers. Meanwhile, more than 4 billion people lack access to medical imaging expertise, according to estimates from the World Health Organization. AI could offer solutions to clinician shortages across the globe and lack of access in some areas by offering remote reading options.

Obstacles lie along the imaging chain in image acquisition, reconstruction, exam positioning and quality control. AI has the potential to rid radiologists of repetitive lower-value tasks to bring time savings and accuracy boosts. It can identify disease with greater accuracy, reduce treatment variability and improve care processes and patient outcomes. It can detect hard-to-see lesions and decrease false-negative interpretations.

AI tools also can enhance image reconstruction, utilizing data more effectively and improving distorted or damaged images. Better worklist prioritization allows the sickest patients to receive quicker diagnoses and treatment, even in hospital settings in which radiologists are not immediately available. And radiology reporting gains consistency.

Machine intelligence is also helping to explore and expose key EHR data to provide a holistic view of the patient. More intuitive interfaces are being created based on caregiver types and easing documentation fatigue.

Beyond individual AI apps, the differentiator for both imaging and healthcare is going to be looking at large, longitudinal datasets, offers Geisinger's Fornwalt. "Where you take a little cross-section of data and look forward and predict from that. That's what machines are good at. We can't do that as physicians…So we're going to leverage that predictive power to make a difference."

The advantage AI brings is a deeper look into the data, Bruce agrees, and "a recognition that there are opportunities to do more with what we're acquiring and what can we unlock." Machine intelligence sees more, differently, which "simply is just not possible no matter how much time a human sits looking at it."

And truth be told, humans are often sitting too long these days.

Burnout is a big issue in radiology, with some 45 percent of radiologists reporting they are burned out, according to recent stats from Medscape that show consistency with last year. "We're talking about data-driven, evidence-driven tools, and we need that," Radiologist Paul Chang, MD, medical director of enterprise imaging at the University of Chicago, said in a presentation at RSNA 2018. "We need the help, because many of us are just barely hanging on."

BUILDING A BACKBONE

A reasonable step that imaging leaders can take today to help their facility embrace AI is preparing their IT infrastructure. IT departments face significant challenges when it comes to integrating AI into an existing workflow, Chang says, but that's a necessary step if you want to actually see benefits once the technologies are ready to be implemented.

"AI is a critical tool, but you don't build architecture for a tool—you build it for a solution," Chang says.

> “Computers make excellent and efficient servants, but I have no wish to serve under them.”
> – Mr. Spock, *Star Trek* (Season 2, Episode 24; 1968)

BLAZING (APPROVAL) TRAILS

Here’s a look at the medical imaging apps that have gotten FDA’s nod:

2017

JANUARY
Arterys: 1st FDA-cleared clinical product to use cloud computing and deep learning; segments and assesses ventricular function from MRI scans of the heart

JULY
Quantitative Insights: 1st FDA-cleared clinical product for ML and DL in breast MRI; ML and DL to evaluate potential breast cancers

NOVEMBER
Arterys: DL to automate cardiac MRI segmentation and measurements

2018

JANUARY
MedyMatch Technology: Analyze head CT images for brain bleeds and automatic notification of treating physician

FEBRUARY
Viz.ai: CT stroke diagnosis

Arterys: AI suite to aid cancer diagnosis in the liver (CT, MRI) and lungs (CT)

MARCH
Imagen: X-ray wrist fracture diagnosis

APRIL
Another 1st, **IDx**’s software detects diabetic retinopathy (DR) *without* a doctor’s help

Icometrix: MRI brain interpretation

2018

MAY
Neural Analytics: Device for paramedic stroke diagnosis

OsteoDetect: ML X-ray wrist fracture detection in adults

JUNE
Bay Labs: Determining echocardiogram ejection fraction

JULY
Zebra Medical: Coronary calcium scoring

AUGUST
iCAD: Breast density via mammography

Aidoc: CT brain bleed diagnosis and automatic notification of treating physician

NOVEMBER
MaxQ AI: Diagnosing and prioritizing CT brain bleeds in stroke and trauma

DECEMBER
Subtle Medical: 1st AI product cleared for medical image enhancement to improve PET image quality

2019

JANUARY
Quantib: On brain MR, measures brain atrophy and white matter changes related to aging, dementia and multiple sclerosis

Source: FDA and web search

A flexible, strong and standards-based platform is essential to enable the organization to capture, enhance, protect and share key data and digital analytics assets.

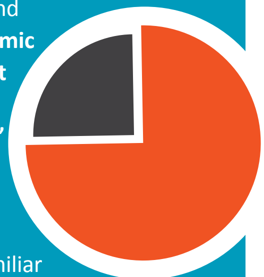
Instead of concentrating solely on the technology, Chang recommends departments focus on the end results they desire. Aim for improved efficiency, for instance, and how AI can help make that a reality. C-suite executives care about improving efficiency because it can save time and, ultimately, money. To build a strategy to integrate AI into your standard workflow, speaking about it in those terms is the way to ensure you get the needed investments.

Radiologists need to be engaged in AI, he says, but realistic on expectations and timing. “The goal is not to be hyped about the technology’s capability,” he says. “You need to be hyped about an infrastructure and interested in improving efficiency and quality simultaneously.”

That’s where vast amounts of data and compute power converge, Wendt notes. “You need to make sure you have a good data processing or automated data pipeline,” he says. “You want to be able to plug in these platforms on the back

RADIOLOGY NEEDS TO COME UP TO SPEED ON AI

A recent survey found about **75% of academic radiologists thought AI and ML would “drastically change” their job over the next two decades**, but only half of the survey base was familiar with big data analytics. The terms AI and ML were unfamiliar to 11% of them.



Source: https://doi.org/10.1016/j.

MACHINE LEARNING 101

SIMPLIFYING IT ONE TERM AT A TIME

- **Confusion Matrix:** This helps readers locate information about a specific term or metric and compare an algorithm with others. It is largely comprised of true-positive and false-positive rate, specificity, accuracy, positive predictive value, likelihood ratios and diagnostic odds ratio. A study may mention an algorithm's accuracy, but what if there are more important metrics a specific instance than accuracy? The confusion matrix helps the reader locate those other metrics.

- **Mean squared error and mean absolute error**: The relationship between variables in ML—regression—are expressed through an equation which minimizes the distance between a fitted line and data point. The degree of regression and its reliability to make predictions is represented by the mean squared error (MSE). "Smaller is better" except in the case of coefficient of determination (R2) metric.

- **Image Segmentation Evaluation:** When the algorithm is designed to detect the presence of something, for instance, it's not just about detecting the finding; it's about looking at its location and size. "The predicted area of interest generated by the algorithm is compared against an ideal or completely accurate evaluation image," the authors wrote. AI

end and have data automatically routed. [Data have] to be routed real time, processed real time, and make the full loop back to the radiologist real time before the radiologist even signs the report. And then loop back to the EMR."

(See "How to Ensure AI-Intelligent Infrastructure" on page 16.)

MAKING A DIFFERENCE

One of the greatest ways AI can provide value to today's radiologists is through improving day-to-day workflow and allowing them to be more efficient. Less time spent on more mundane tasks equals more time spent reading studies and helping patients. NLP can help with mundane tasks as automated image segmentation helps with labeling, measurement and comparing newer studies with prior studies.

Looking at AI with a broader brush stroke, the true difference machine intelligence will bring is in the care of individual patients and populations over time. Analyzing longitudinal data, improving insight and decision-making today and reaching back into that data as the evidence base evolves, best practices change and guidelines advance to offer more effective methods of diagnosis, prevention and treatment.

"I think as we move forward [over] the next five years, it's not just going to be about the algorithms," Bruce says. "It's going to be about proving what is the real value to the people who ultimately are consuming it."

Radiology, too, offers great value to the evolution of care aided by machine intelligence. Two researchers from the Japanese Radiological Society put it this way. "AI can be expected to gradually change clinical practice by helping radiologists practice with better performance, greater interrater reliability and improved workflow for more timely recommendations," they wrote in the *PLOS Medicine* Special Issue on Machine Learning in Health and Biomedicine. "Radiologists will be important in labeling training datasets and developing new knowledge from image data. In the clinic, even if current deep learning approaches broadly excel in image interpretation, radiologists will continue to play central roles in the diagnosis of rare diseases and in the detection of incidental findings."

For the doctor's doctor, now is the time to consult AI and define the strategy to lead the charge to more consultative medicine. AI

RECOMMENDED READING:

- Data Science Institute, American College of Radiology: www.acrdsi.org/
- RSNA: https://www.rsna.org/education/ai-resources-and-training
- Methodologic Guide for Evaluating Clinical Performance and Effect of Artificial Intelligence Technology for Medical Diagnosis and Prediction: https://doi.org/10.1148/radiol.2017171920
- Deep Learning: A Primer for Radiologists: https://doi.org/10.1148/rg.2017170077
- Current Applications and Future Impact of Machine Learning in Radiology: https://doi.org/10.1148/radiol.2018171820
- When Machines Think: Radiology's Next Frontier: https://doi.org/10.1148/radiol.2017171183
- Machine Learning for Medical Imaging: https://doi.org/10.1148/rg.2017160130

> “The world’s most valuable resource is no longer oil, but data.”
>
> – David Parkins, *The Economist*

4 QUESTIONS

NYU’s Daniel Sodickson on Why Facebook Partnership May Speed Up MRI

A new project is seeking to make MRI scans up to 10 times faster by capturing less data. NYU’s Center for Advanced Imaging Innovation and Research (CAI2R) is working with the Facebook Artificial Intelligence Research group to “train artificial neural networks to recognize the underlying structure of the images to fill in views omitted from the accelerated scan.” If MRI gets faster, it could potentially push aside X-ray and CT for some applications and avoid ionizing radiation. Here’s Daniel Sodickson, MD, PhD, vice chair for research in radiology and director of CAI2R’s take on the project.

How did NYU connect with Facebook on this project? We have been working on accelerating MRI by any means available. In 2016, we described some of the first uses of deep learning for image reconstruction from accelerated data acquisitions, and now that is an exploding area in MR research. A colleague at NYU connected us with the Facebook AI group. The challenge of reconstructing fast MR images from limited data really appealed to them, both because it raised fundamental questions for AI and because it addressed a problem with a significant impact.

Why the need to speed up MRI scans? AI can help us gather data in new ways. Speed is one of the fundamental currencies of imaging; the faster you can go, the more information you can get. MRI can generate multiple views of the body, looking at anatomy, function and cellular microstructure. The exams typically take 15 minutes to an hour or more, which can be a real impediment when dealing with patients with chronic illness or children who struggle to stay still for extended times.

What impact could this have on healthcare? It would create a more comfortable patient experience, as well as increasing MRI accessibility in areas where there is limited access to scarce and/or oversubscribed MR machines. Faster MRI also can mean improved image quality. We’re talking about increasing the shutter speed, so that we can freeze out motion and see anatomy more clearly.

NYU and Facebook have indicated plans to open-source this research as the work moves forward. Why? We will open-source both our methods and the architecture we are using so that other researchers can work with them. We’ll also open-source the dataset, giving people access to highly specialized data that are generally difficult to gather but essential for the success of modern AI techniques like deep learning. AI

–As told to Michael Walter

AI Detects More Variation in Free-text vs. Structured Radiology Reports

A natural language processing (NLP) and machine learning algorithm trained by Stanford researchers to evaluate variation in radiology reports found more variation in free-text reports than structured reports—with a ten-fold difference in scores among radiologists.

The research, published in *Current Problems in Diagnostic Radiology*, analyzed more than 28,000 radiology reports for four metrics: verbosity, observational terms only, unwarranted negative findings and repeated language in different sections of the report. They looked at reports for appendicitis ultrasound (structured) and single view chest x-ray (unstructured). Radiologists were ranked based on the number of metrics identified in each report.

“The power of NLP lies in its ability to analyze the vast amounts of … ‘unstructured data’ and make decisions based on the content,” the authors noted. The study showed that NLP and ML can identify metrics to help with “quality control, teaching, and as feedback and learning materials for practicing radiologists.” AI

INTELLIGENCE & INSIGHT

The Latest News in AI and Machine Learning

AI MARKET TO GROW TO $36.1B BY 2025

The healthcare-focused artificial intelligence market is expected to see 50 percent growth through 2025, according to a report by MarketsandMarkets.

Here are five key trends:

1. The AI in healthcare market was valued at $2.1 billion in 2018.
2. It is expected to grow to $36.1 billion by 2025, at a compound annual growth rate of 50.2 percent during the forecast period.
3. Machine learning is anticipated to hold the largest share of the market, followed by natural language processing.
4. The drivers are increasingly large and complex data sets, growing need to reduce increasing healthcare costs, improving computing power and declining cost of hardware.
5. The challenges are reluctance of medical practitioners to adopt AI-based technologies, lack of skilled workforce and ambiguous regulatory guidelines for software. AI

Healthcare, Meet the Chief AI Officer

The C-suite has a new addition: the Chief Artificial Intelligence Officer. And as best we can tell, Anna Goldenberg, PhD, is the first. She was named chief of biomedical informatics and artificial intelligence at The Hospital for Sick Children in Toronto in January.

"I feel like right now as a computer scientist, as a researcher in machine learning and AI, I can actually make a big difference in healthcare," Goldenberg told *The Globe and Mail*. "It will take time, but I think we are getting closer and closer to seeing it happen."

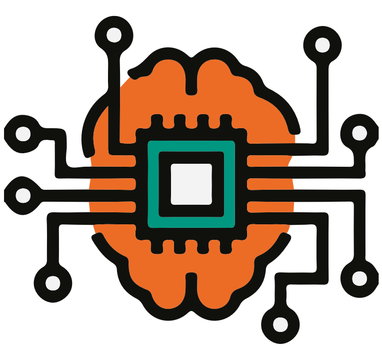
And truth be told, AI is powering AI. Goldenberg's post is funded in part by a $1.75-million donation from a Toronto engineer and entrepreneur whose newborn son underwent surgery at Sick Childrens. The entrepreneur co-founded a company that developed a software platform for connecting self-driving cars to smart infrastructure that was sold to Ford Motor Co. last year. The rest of the position is being matched by hospital's fundraising foundation, bringing the total donation to $3.5 million.

Goldenberg, who has a master's degree and PhD in data mining and machine learning, currently serves as an associate professor of computer science at the University of Toronto and is a senior scientist at the hospital. Her research focuses on using machine learning to map human disease heterogeneity and using patient data and AI to predict cardiac arrest. AI

Drum Roll, Please: AI Earns 1st Peer-Review Nod

It's been a long time coming, but the first-ever retrospective study on AI was published online in *The Lancet Oncology* in August. The study sought to develop a score to predefine responders to cancer therapy and improve the efficacy and cost ratio of treatment.

This tap of the peer-reviewed wand establishes that artificial intelligence can process medical images to extract biological and clinical information. This means physicians soon may be able to use imaging to identify tumor biology in any part of the body without having to perform a biopsy. If the team hadn't demonstrated its feasibility, the technique would sound like sci fi.



Here's how the research team did it. They designed an algorithm to analyze CT images. The image data were combined with a "radiomic signature" that defines the level of lymphocyte infiltration of a tumor and offers a predictive score for the efficacy of immunotherapy in the patient. The radiomic signature was captured, developed and validated in 500 patients. The team found that patients in whom immunotherapy was effective at 3 and 6 months had higher radiomic scores as did those with better overall survival. AI

HERE'S SOME IRONY.

Just as AI is recognized in a peer-reviewed journal, it seems the *Lancet's* parent company is beginning to pilot AI tools to ease the peer-reviewed publishing grind by helping to check statistics, summarize paper findings, improve the review process and boost the quality of published papers. Hmmm, AI supporting AI. But we're pretty sure they aren't related. (Get the lowdown in *Nature*) AI

Building AI 'Machines With Morals'

In this age of intelligence, there's a new center with a new mission to inspire and influence public policy and regulations on the ethics of AI and building "machines with morals." The Center for Advancing Responsible and Ethical Artificial Intelligence (CARE-AI), established at the University of Guelph in Ontario, is focused on ensuring technologies benefit people, minimize harm and maintain the human side of technology.

The center is bringing together 90 university researchers and scholars who plan to analyze the humanistic and social aspects of AI and investigate methodologies, such as learning algorithms, human-computer interfaces, data analytics, sensors and robots in the areas of human and animal health, environmental sciences, agri-food and the bio-economy. Among the issues they will probe are AI's potential to become entities with emotion and consciousness, and how humans and AI will interact as intelligent machines begin to design themselves.

Mayo Team Finds 'Silent' Heart Disease

Applying artificial intelligence to an electrocardiogram can help identify asymptomatic left ventricular dysfunction, a precursor to heart failure. A team of researchers from Mayo Clinic published a study in *Nature Medicine* showing they can do just that.

The team used Mayo Clinic data to screen 625,326 paired EKG and transthoracic echocardiograms to identify the patient population. Then they created, trained, validated and tested a neural network to test their hypothesis, finding the accuracy comparable to other common screening tests.

Interestingly, in patients without ventricular dysfunction, those who had a positive AI screen had four times the risk of developing future ventricular dysfunction, compared with those with a negative screen, the study found.

"In other words, the test not only identified asymptomatic disease, but also predicted risk of future disease, presumably by identifying very early, subtle EKG changes that occur before heart muscle weakness," according to senior study author Paul Friedman, MD. AI

"For an industry known for its glacial approach to change, AI offers more than a little light at the end of a long tunnel."

– *HBR*

HBR: AI MAY CUT HEALTHCARE'S RED TAPE

Could AI be the solution to stop the "downward spiral in productivity" in the U.S. healthcare system plagued (since World War II) by labor-intensive and inefficient administrative tasks? Absolutely, according to an article in *Harvard Business Review*.

AI tools capable of processing vast amounts of data and making real-time recommendations could greatly reduce the administrative burdens in the healthcare system–and save money to boot. According to the article, about one-third of the $3 trillion annual costs of the U.S. healthcare system are administrative and operational inefficiencies. AI already is enabling faster hospital bed assignments, easier and improved documentation and automated fraud detection. For example, AI helped one health system assign beds 30 percent faster, reduce time in recovery by surgical patients by 80 percent, cut ER bed wait times by 20 percent and accept 60 percent more transfer patients.

To take advantage of AI, the authors say healthcare organizations need to:

- Simplify and standardize data and processes so AI can work with them
- Ensure interoperability and data sharing among IT systems
- Phase out staff who do not add value to the business by helping improve outcomes AI

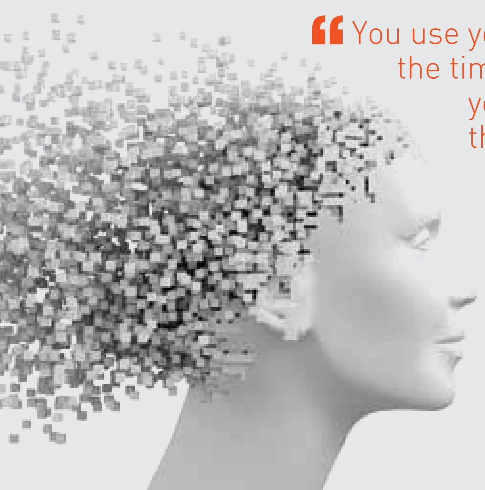
Blacking Out the 'Black Box' Challenge?

Using fewer than 1,000 imaging cases, researchers from Massachusetts General Hospital in Boston were able to train an AI algorithm to detect intracranial hemorrhage (ICH) and classify its five subtypes on unenhanced head CT scans (*Nature Biomedical Engineering)*. The deep learning algorithm was designed to reveal the reasoning behind its decision, often called AI's "black box" problem, through an "attention map" that highlights important regions on the images used to make its predictions. It also eliminates the need for radiologists to annotate the large, high-quality data sets used to train most deep learning models.

The research team found the model performed with comparable accuracy but higher sensitivity than trained radiologists.

Here's why it really matters: Brain hemorrhage is a potentially fatal condition, having an automated sensitive model that reliably detects it can expedite treatment for patients. It also may help neuroradiologists of varying levels of expertise determine the presence or absence of bleeding from a brain scan sooner and avoid delayed or missed diagnoses of ICH. AI

Pierre Baldi, a machine-learning researcher at the University of California, Irvine, thinks scientists should embrace deep learning without being too obsessed about the black box. After all, they all carry a black box in their heads.



"You use your brain all the time; you trust your brain all the time; and you have no idea how your brain works."

(*Nature,* 10/5/16)

AI Tool Detects Skin Cancers Better Than Dermatologists

Put one in the win column for AI. That was the result when an AI-based network outperformed dermatologists in analyzing images of skin lesions for cancer, no matter the experience level of the physician, according to a recent study the *Annals of Oncology.* Dermatologists, however, performed better after adding real-life clinical information to their diagnoses, but were still outperformed by the neural network.

"Our data clearly show that a CNN [convolutional neural network] algorithm may be a suitable tool to aid physicians in melanoma detection irrespective of their individual level of experience and training," wrote author Holger A. Haenssle, MD, a professor with the department of dermatology at the Heidelberg University in Germany. AI

On the Verge: DL Predicts Breast Tumor Response to Chemo

Get ready for precision medicine. Case in point: Researchers have predicted with 88 percent accuracy how breast tumors will respond to neoadjuvant chemotherapy (NAC), according to new findings published in the *Journal of Digital Imaging*. The benefits are twofold: providing a better approach to assess treatment response early and "significantly" improving on current prediction methods that rely on interval imaging once therapy is started.

Using a breast MRI tumor dataset, researchers at Columbia University Irving Medical Center in New York employed a deep learning convolutional neural network (CNN) approach to train and predict response to chemotherapy prior to its initiation on 141 patients.

"Our early prediction model of treatment response has the potential to impact clinical management in patients with locally advanced breast cancer, including the opportunity to direct appropriate therapy in non-responders, minimize toxicity from ineffective therapies, and facilitate the upfront use of novel targeted treatment in the neoadjuvant setting," the authors wrote.

What's next? Larger datasets to improve the model and ultimately help move it toward clinical implementation. AI

Amy Baxter, Danielle Brown, Melissa Rohman, Subrata Thakar, Mary Tierney and Michael Walter contributed to these stories.

THE NUMBERS: HOW THE C-SUITE EYES AI

Enabling Better Patient Experience: 6 Key Findings

Some 80 percent of healthcare executives expect AI will be integrated into the patient experience within two years, according to a survey by Accenture. The 100 executives surveyed were divided evenly among health systems and payers.

Here are the key findings:

92% believe the security of consumer data is important in building trust with customers

91% believe blockchain will be critical to the industry within three years

88% agree the volume of data exchanged with partners will increase over the next two years

86% of organizations are focusing critical systems on data but have not invested in verification

81% are concerned their organizations are not ready for the societal and liability issues that will result from this change

73% plan to develop internal ethical standards related to AI so the systems are designed responsibly

Big Investments in Big Data

The groundswell you feel around AI is real. More than 75 percent of healthcare executive leaders polled said their organization is increasing the pace of investment in big data and AI, according to a survey by NewVantage Partners.

What's driving the surge? More than 87 percent reported feeling a greater urgency to invest. Of those firms, 92 percent named business transformation and greater agility the biggest drivers of their investments. Fear of disruptions was the biggest driver of big data and AI investments for 79 percent of execs. But the good news is 57 percent of healthcare firms report they're competing effectively on both data and analytics.

ROI Is Driving Confidence

Healthcare executives and organizations are extremely confident AI will bring solutions to some major challenges: better predicting disease, putting intelligent insight into the hands of clinicians at the point of care and reducing cost. In fact, that confidence is driving an average expected investment of $32.4 million each in AI over the next five years across 500 health execs surveyed by Optum. More accurate diagnosis and increased efficiency are the top two benefits healthcare leaders expect to see after incorporating AI into their organizations

Here are some noteworthy stats:

94% agree AI technology is the most reliable path toward equitable, accessible and affordable healthcare

92% say hiring candidates with experience in AI technology is a priority

90% are confident their organizations will see a return on investment from AI

75% are actively implementing or have plans to execute an AI strategy

42% already have a strategy that has yet to be implemented

36% expect AI to improve the patient experience

31% believe AI will improve health outcomes

22% say their AI implementations are at a late stage, with nearly full deployment

Of healthcare organizations already investing in AI:

42% are using AI to automate business processes

36% are using AI to detect patterns of fraud, waste and abuse

31% are using AI to monitor users with Internet of Things (IoT) devices

BULLISH ON AI: THE WISCONSIN WAY

REENGINEERING IMAGING & IMAGE STRATEGY

by Dave Pearson

Not just for years but for decades, the department of radiology at the University of Wisconsin School of Medicine and Public Health in Madison has been leading the charge on creating innovative technology and translating imaging research into clinical practice.

Here we find some of the most progressive thinking and well-defined strategy in the revolution that is artificial intelligence. UW Health professionals are creating ways to "see" where humans cannot, better harnessing structured and unstructured data, and driving more predictive medicine. The research is advanced and vast, and the clinical translations are ahead of the curve.

For example, the department is the vanguard in virtual colonography, having built a repository of 10,000-plus image datasets for training. When brought to bear on medical questions from real patients and their doctors, ML-powered innovation will not only find polyps and cancers of the colon but also flag incidental findings and drive best practices to improve patient health. More actionable insight is always the goal.

At the birthplace of digital subtraction angiography and many methods for CT reconstruction, new work in ML and DL are refining image processing and reconstruction, enhancing image interpretation and reducing EHR burdens for physicians. They're also looking within radiology at areas such as bringing CT image quality to PET/MR and beyond to dermatology and ophthalmology.

Further, each month the school brings together radiologists, medical physicists and biomedical engineers, among other credentialed enthusiasts of medical AI, to discuss machine learning (ML) research in a focus-group setting.

The number of UW labs now using ML applications as investigational techniques is "somewhat staggering," says Richard Bruce, MD, medical director of radiology informatics. "We have one of the largest medical physics departments in the world, with approximately 30 faculty and dozens of scientists and graduate students. There probably is not a single area that is not actively involved in using machine learning in some way."

> We want to be able to bring out features and actionable data, particularly structured data, that even a great radiologist could never come up with, no matter how hard he or she looked at the images.
>
> Gary Wendt, MD, MBA, Enterprise Director of Medical Imaging and Vice Chair of Informatics, University of Wisconsin School of Medicine and Public Health

Given all that, it's no wonder the scientific publisher Elsevier recently ranked UW's radiology department third in the world for its impact on the field of medical imaging.

"A ton of work is being done here now" with machine learning, says John Garrett, PhD, director of radiology informatics. "We may be a little less focused than some other places on detection-type tasks or [cancer] classification, but we're getting a lot done on image processing and image reconstruction," not to mention image quality control and worklist prioritization for diagnosticians.

One of the department's major focuses with ML is supplying radiologists with heretofore unattainable image data. An especially keen interest is using algorithms to extract aspects of images the radiologist could not possibly see "even if you had an hour to visually scour the images," explains Gary Wendt, MD, MBA, enterprise director of medical imaging and vice chair of informatics. "We want to be able to bring out features and actionable data, particularly structured data, that even a great radiologist could never come up with, no matter how hard he or she looked at the images."

Wendt, Bruce and Garrett shared their thinking on the current state and future outlook for AI in medical imaging in a roundtable discussion with *AI in Healthcare*.

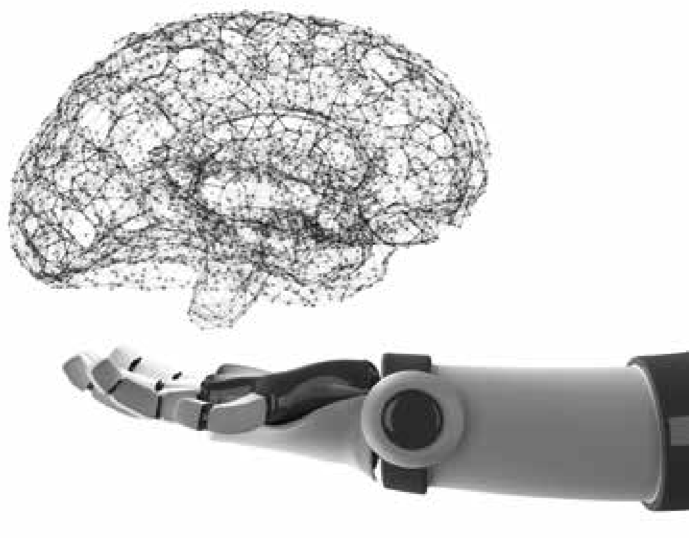
TOWARD A MORE PERFECT EHR

Wendt, who is regarded by many in the broader medical imaging community as a pioneer of the radiological sciences, emphasizes that UW's work with ML for image analysis extends beyond radiology. In fact, the institution has been working with visible-light imaging—aka photography and video—for more than a decade and a half. "This is going to be a very important area for deep learning in the future," Wendt says before citing as examples melanoma photos from dermatology and retinopathy images from ophthalmology.

"If there are not enough ophthalmologists to screen every patient who has diabetes, and you had an AI algorithm that detected early diabetic retinopathy, you could plug in the critical patients and get them the care they need sooner," Wendt says. He points out that, for patients, this scenario would represent a financial as well a medical victory: Diabetic retinopathy that leads to blindness both tragically changes a life and costs a lot to care for.

Building on its promise to help with discrete diagnoses in particular circumstances, ML also stands to help electronic health records (EHRs) deliver on their potential to present clinicians with a holistic view of each patient so they can treat not just a condition but also a person. They seek to offer clinicians the most essential view of the patient at the time of care as well as shining light on patient and population data longitudinally and even into the future to improve health and care.

"The adoption of EHRs is to a level where they can deliver all the clinical care, and there is finally the opportunity to be able to focus on how to use that data, how to deliver a better experience, how to optimize things," says Bruce. Look for AI to build predictive algorithms that can be directly integrated into the EHR, he says.



How to Ensure AI-Intelligent Infrastructure

When digital imaging was new a couple decades ago, many radiology departments got by with standard desktop computers and optical discs. Spill your coffee on a disc, and there went a patient's medical images. Quickly for some, eventually for everyone, the day came when it was clear that radiology needed to up its game with medical-grade monitors and data-storage solutions.

So recalls Gary Wendt, MD, MBA, enterprise director of medical imaging and vice chair of informatics in the radiology department at the University of Wisconsin School of Medicine and Public Health.

"The same thing has to happen with deep learning," Wendt says. "If we're taking the data out of the research realm, and we want to move it into a translational and clinical realm, we have to take our hardware up a notch so we have the ability to handle all these data. We have to make our infrastructure 'data center grade.'"

John Garrett, PhD, the institution's director of informatics, says one of the challenges this infrastructure aim presents is dealing with uncertainty over what form the data are going to take. One answer, he suggests, is prioritizing scalability of storage to achieve higher performance with centralized computing infrastructure.

Garrett encourages healthcare CIOs charged with integrating AI to "figure out a framework where you don't have to know exactly what you want, but you can bring a breadth of data very close" to what you'll need. "That way, when certain types of data are needed, they're already right at hand."

Richard Bruce, MD, medical director of radiology informatics, advises keeping in mind the evolution that's unfolded over time in best practices for infrastructure management.

"Years ago, radiology acted almost autonomously in how we managed our infrastructure," Bruce says. "We've had a philosophy for a long time that we believe in the concept of enterprise imaging. And that means we also believe in being an enterprise partner in all of this."

At UW, that belief is fueling a "long, ongoing conversation," Bruce adds, about how to integrate radiology's computing needs with those of the enterprise as a whole.

The conversation has led to "economies of scale at the enterprise level from an infrastructure perspective," Bruce says. "Hopefully we've been catalysts and encouragers for our enterprise to look at some of the infrastructure investments that are really necessary to move around large quantities of data." AI

"A lot of it is really about the nuts and bolts of looking at what's there and figuring out how you can do a better job with the data that already exist. It's dealing with the data overload," Bruce adds. "It's not necessarily always about providing something completely new but about how to simply bring attention to the things that are already there. How do we reduce the noise? How do we bring to the top all those related things... so we can paint the most compelling picture, story, of the patient."

That includes cutting through the din of information overload and helping to triage patients as well as guide steps in their care pathways. In radiology, for example, this means prioritizing work lists so that radiologists read the most urgent imaging exams first. Referring physicians benefit by both getting results fastest on patients who need intervention soonest and by collaborating with radiologists who can.

EXTENDED LIFESPANS FOR DYNAMIC DATA

What sort of computing power will it take for medical informaticists to support clinicians in this emerging world of machine-aided image analysis, disease diagnosis, case prioritization and care decision-making? A lot, and the UW team is refining its data strategy and plan.

"Over the next five years or so, one of the biggest changes in informatics is going to be a transition from data collection, data consumption and data archiving to a model where data are collected and stored, but they're readily available to be used again and again," Garrett says.

Images won't be processed and consumed—meaning interpreted—only to be set aside. Rather, clinical data will continually be revisited to guide decisions around future episodes of care.

"From an informatics standpoint, one of the most dramatic shifts is going to be toward a transient storage type of framework," Garrett continues, "where data are being held very close so they can be brought up and used for a variety of purposes."

As this long-view management of clinical data becomes ubiquitous, the practice of radiology will be elevated, Wendt suggests.

Machine learning is "going to make us more efficient, make us produce better output, so that our reports are more consumable," Wendt says. "In the near term, that's going to be the big benefit. Longer term, data scientists like John Garrett are developing algorithms that we're now just dreaming about."

> “It’s not necessarily always about providing something completely new but about how to simply bring attention to the things that are already there. How do we reduce the noise? How do we bring to the top all those related things…so we can paint the most compelling picture, story, of the patient.”
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TRANSFORMATIVE TIMES

Garrett doesn’t shrink away from the implied friendly pressure. Quite the opposite. He sees ML in the near future facilitating closer collaboration among and between medical specialties that have grown distant from one another due to the sheer volume of clinical knowledge that medical research has produced over the years. Sometimes, he notes, there’s even a chasm between subspecialties within a given specialty.

“It’s very difficult to be a state-of-the-art facility without people in siloes,” Garrett says. “One of the potential advantages of AI, both in radiology and in medicine generally, is that it can start to bridge some of those specialties and subspecialties.”

Garrett gives as an example the nuanced, finely specific data on brain structure now available. “You have a neuroradiologist who has read an imaging exam and has dictated a report that is really tailored to his or her expertise,” he says. With a little help from an AI app, a neurosurgeon on the receiving end of the report “may be able to do even more than they can now.”

Bruce also sees big changes for the role of the radiologist in the era of AI. “In many ways,” he says, “AI will help us to deliver deeper, richer, more contextually sensitive information to providers. It will make us better [clinical] consultants than we can be today.”

Wendt nods in agreement, offering that AI and ML will enable a more proactive approach to medicine than has been possible up till now. This might be nowhere more evident than in cases where an algorithm makes an incidental finding, such as the virtual colonography solution mentioned earlier.

“You’ll be able to actually identify areas of problems that really weren’t questioned,” Wendt says. He names as another example a patient sent for a trauma CT following a fall or car accident. An algorithm will tell if the patient has osteopenia, or weakening of the bones, from that same exam “where that really wasn’t the clinical question that was asked by the trauma physician who ordered the CT scan.”

Bruce amplifies one of the most commonly cited benefits of ML for radiology—handling basic yet time-consuming tasks such as measuring, quantifying and segmenting tumors.

“You can see that as better efficiency for radiology, or you can see it as the patient and medicine in general deriving more value and benefit from exams that are already ordered or completed,” Bruce says. “This is a unique time. It’s a transformative time in medicine.” AI

VIDEO ROUNDTABLE
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https://aiin.healthcare/node/129731

LEVERAGING TECHNOLOGY, DATA AND PATIENT CARE

HOW GEISINGER IS INTERJECTING INSIGHT & ACTION

by Dave Pearson

As an integrated health-delivery network comprising 13 hospital campuses, two research centers and a health plan with more than half a million subscribers sitting atop the biggest biobank with whole exome (DNA) sequence data in existence, Pennsylvania's Geisinger Health System is one of the best-positioned institutions in the U.S. to explore the possibilities and initial successes of AI in healthcare. The institution is bringing complex algorithmic concepts to everyday patient care and showing others the path forward.

There's a lot to learn from Geisinger. The system serves more than 3 million residents in central, south-central and northeastern Pennsylvania plus southern New Jersey. Here's their prowess: As an early adopter of electronic health records, they have 20-plus years of longitudinal views of a stable population of 2 million people, a centralized data warehouse stretching back to 2007 and extensive imaging databases. DNA sequencing is now being added to the mix. Numerous AI-related studies are in progress here, thanks to the massive homegrown datasets and closely aligned research and clinical teams seeking to improve the care of individual patients and populations. They seek to spread the word that, in the age of artificial and augmented intelligence, every hospital team needs to get onboard to utilize their own data to treat, support and improve the care and health of their patients.

Four leaders with key roles in activities guided by this mission explained the emphasis to *AI in Healthcare*.

'TRANSLATIONAL FIRST'

"Everything we do is about translating research into clinical practice," says Chair of Department of Radiology at Geisinger Aalpen Patel, MD. "Research for research's sake, there's a place for that [and needed to understand the basic science]. But our focus at Geisinger has been translation first."

"If you look at the literature, you'll find there are a lot of papers out there" with AI in the title, says Brandon

> "We highly value the analysts who understand the data that are available, the governance that goes under it, the strengths and limitations thereof, and are able to be the intermediaries between the raw data and the data that the model builders are looking for."
>
> Christopher Haggerty, PhD, Biomedical Engineer and Co-director of the Cardiac Imaging Technology Lab (CITL) within Geisinger's Department of Imaging Science and Innovation

Geisinger's imaging computing sits on 1 petaflop of computer processing power.

> "Just to put that in perspective, the world's most powerful computer has 200 petaflops. So this is some serious compute power, and our teams are actually using it up. We always need more compute power. The data mandates it."

Aalpen Patel, MD, Chairman of System Radiology, Geisinger Health System

Fornwalt, MD, PhD, a radiologist who chairs Geisinger's Department of Imaging Science and Innovation and also directs the Cardiac Imaging Technology Lab (CITL). "They get published, and they're great papers. But there's no implementation. And then review articles are written about those papers, which leads to the proliferation of the hype we're seeing in the medical AI field right now."

At the same time, underlying every translational initiative is a dedicated research project that helped get Geisinger to the point at which care quality can be significantly improved by machine learning based on scientific evidence. Christopher Haggerty, PhD, a biomedical engineer and Fornwalt's co-director at the CITL, jumps in to make sure this aspect doesn't get short shrift.

As an example, he describes Geisinger's work to build an AI model that can predict disease severity for patients with heart failure while also predicting the potential benefit from specific targeted interventions, such as getting an annual flu shot. That work has expanded as the team behind it seeks to roll out the model to Geisinger's pharmacy group, whose members will further test and deploy it for patients. This development built on many "preceding months of work to understand what are the important inputs that we need to be considering and curating," Haggerty says. "How do we build the model, and what do we do with it once we have it?"

Adding the IT and enterprise perspective, Geisinger's Chief Information Officer John Kravitz, CHCIO, MHA, stresses the importance of collaboration that bridges not only research labs with patient-care areas but also multidisciplinary teams with former departmental silos. "We have the luxury, working in IT especially, of having the respect of clinicians, because we provide them with tools. It's a bi-modal, bi-directional respect," Kravitz says. "That goes a long way to help our patients."

MULTI-MODAL DATA FEEDS

While Geisinger's translational research spans myriad medical specialties and disease states, its work applying AI to help head off heart failure is illustrative. The efforts began with vital signs, laboratory and diagnostic data, and measurements derived from echocardiograms and is now incorporating data from 12-lead electrocardiography (ECG) readings. The team is using data from 2.5 to 3 million historical ECG studies, and the hope is to also build predictive models for everything from atrial fibrillation to stroke.

Next, tapping the institution's genomic data, the team will integrate data from all three sources—echocardiography, ECG and genomics—into a multi-modal machine learning algorithm.

"If you can say a patient has a 70 percent probability that, within a year, he or she is going to develop atrial fibrillation based on the historical data, you can monitor that patient very closely," says Patel. "This is important, because when you have undiagnosed atrial fibrillation, you're at a much higher risk of stroke."

Studies at Geisinger and elsewhere have already shown that a physician can't predict future heart events nearly as well as a computer can, says Fornwalt, adding that 95 percent of medicine is about prediction. "We're going to leverage machine learning's predictive power to make a difference," he says. "We can give you a heart monitor that you stick on

your chest for 14 days, pick up the readings, put you on an anticoagulation med so you don't present with a stroke that destroyed half your brain and now you can't move the left side of your body. That's a game changer."

> "The machine learning models can actually predict future events even in those 'normal' ECGs ... This is like AI for a whole new area of medicine that doesn't even exist right now."
>
> Brandon Fornwalt, MD, PhD, Radiologist and Co-director of the Cardiac Imaging Technology Lab (CITL) within Geisinger's Department of Imaging Science and Innovation

PREDICTIVE VALUES

Fornwalt is equally enthusiastic about the ECG project's potential to aid in initial diagnosis of asymptomatic heart disease. There might be a subset of 100,000 of those 2.5 to 3 million historical ECGs labeled *normal* by the physician but some may not be so normal after all.

"The machine learning models can actually predict future events even in those 'normal' ECGs," Fornwalt says. "This means they're probably not normal. There's something subtle inside of those ECGs that the physicians are not picking up on, and yet it predicts [a heart event] in the future. This is like AI for a whole new area of medicine that doesn't even exist right now."

CIO Kravitz shines light on how such predictive medicine, when extrapolated to multiple health conditions across Geisinger's catchment area, can both improve health and drive down costs at the level of population health.

Geisinger provides care for about 40 percent of its 600,000 or so health plan subscribers, he notes. "It behooves us to keep those patients as well as possible, keeping them out of the acute-care setting," Kravitz adds. "We can bring a patient in, maybe in an ambulatory setting, and take care of a problem. For health systems that are paid a certain amount, the better you can treat a patient through the use of AI and ML tools, the better you will do financially as a health system. And then, on the flip side, we can teach patients that holistic care does a lot more to help you have a better quality of life and a longer life."

GOVERNING AI GROWTH

The four Geisinger experts agree that three things are key to making AI a difference-maker in any healthcare system—data governance, multidisciplinary collaboration and computing power.

"We look at everything from a data governance perspective to make sure the data are pristine and correct and mean one thing across the organization to everyone who's going to use that data," Kravitz says.

"We don't have this all figured out by any stretch of the imagination," Fornwalt adds. "We've had an EHR for more than 20 years, so we're fairly far along. But we're still going back and forth about how to define heart failure in the best way. So good data governance is absolutely critical."

Even the soundest data governance wouldn't do much to enable AI if efforts were siloed, says Haggerty, adding that making sure the data are available and sharable by multidisciplinary teams throughout the enterprise is vital.

"The people who are building the machine learning models and doing that end of the analysis tend to be the higher-profile individuals," Haggerty says. "But also we highly value the analysts who understand the data that are available, the governance that goes under it, the strengths and limitations thereof, and are able to be the intermediaries between the raw data and the data that the model builders are looking for."

IDENTIFIABLE INFRASTRUCTURE

Also enabling the underlying processes that encourage AI to sprout from research and bloom in patient care is pure computing "horsepower," the four agree. This is nowhere more evident than when working with multi-modal data, as Geisinger has found with the ECG–echocardiography–genomic data flows, among others, Fornwalt says.

"We've found that you have to have very fast ways to process that multi-modal data with very fast storage," he adds before underscoring that the storage must reside very close to where the data lives for daily clinical use such that clinical workflows are not disrupted.

To support all the work Geisinger is doing with machine learning, leadership is behind the concept of placing everything "in one spot," Fornwalt says, so that all involved parties can tap the very high-performance compute GPU clusters and do their best work.

> “Typically in IT systems you have storage area networks, which is a big disk array. Whether it’s flash memory [or some other solution], we need to have a high-volume cluster where the data and the compute power are locally attached, so it’s very fast in computing.”
>
> John Kravitz, CHCIO, MHA, Chief Information Officer, Geisinger Health System

“We are one of the only hospitals that has that type of infrastructure built inside the clinical network,” he says. “We keep it all in an identified space where it’s secure and protected, and we build that infrastructure inside of that space.”

At many other institutions, he continues, researchers and innovators “are sitting outside the clinical network, and they’re begging for data. Most places have a very slow pipeline to get that data out for the researchers and innovators.”

Part of the problem is that data are often de-identified to protect patient privacy, and de-identification processes slow things down and sometimes compromise the integrity of the data. Fornwalt says Geisinger opted to build a space inside the clinical network to keep the data-sharing process simple and efficient without compromising privacy and security.

FAST COMPUTE

This was a logical choice, given Geisinger’s view of compute power as mission-critical.

“Typically in IT systems you have storage area networks, which is a big disk array,” Kravitz says. “Whether it’s flash memory [or some other solution], we need to have a high-volume cluster where the data and the compute power are locally attached, so it’s very fast in computing.”

To give an example, Kravitz describes Geisinger’s big-data platform. “We use tools that let us pull up 2 million encounters in less than 1 second so we can look at myocardial infarction. That’s how fast it functions,” he says. “It’s all super-indexed. That’s the way this process works, and it’s necessary to support our clinicians so they can get quick results and have tangible data to work from.”

Geisinger’s imaging computing sits next to a GPU cluster with 1 petaflop of processing power. “That’s a million billion floating point operations per second, or FLOPS,” Patel explains. “Just to put that into perspective, the world’s most powerful computer has 200 petaflops. So this is some serious compute power, and our teams are actually maxing it out. We always need more compute power. The data mandates it.”

EXCITINGLY TERRIFYING

To wrap up the discussion, *AI in Healthcare* asked each about their long-term goals with AI at Geisinger:

- **Patel**: “The ultimate question we need to be asking is: How do I help the patient? Part of that [equation] is going to be helping physicians take care of patients. But there will be other parts [variables] to taking care of the patient even better. Ultimately the shift will happen from physician centricity to patient centricity.”
- **Fornwalt**: “I became a physician-scientist because I wanted to change lives in a positive way. I believe that we at Geisinger can lead the implementation of AI and machine learning in healthcare and show the world what’s possible. I strongly believe that what we do here can be translated to other places. And we can improve the lives of our patients, helping them live longer and happier lives. That’s why I come to work.”
- **Kravitz**: “Not being a physician, but looking at it from a commonsense perspective, if you can treat a large population of patients cost-effectively, and improve their quality of life, isn’t that what we’re here for? It’s discrete and predictive medicine, to look at health problems that people aren’t even aware they have. If you can intercede in those problems and improve someone’s quality of life, that’s really what we want to achieve here.”
- **Haggerty**: “When you talk about the opportunities with the genomic data and the image data that we have—all of that is special and unique. To not leverage that and capitalize on that opportunity to make a difference and do so in a way that is both special and powerful would feel like a shame.”

The last word goes to Fornwalt, who says AI in healthcare is, at the present moment, equal parts exciting and terrifying. “I’m stressed out,” he says, “because I’m thinking: *What’s hiding in these data that we’re not acting on, that we need to be doing right now to help our patients?*” That’s a motivator for sure. AI

VIDEO ROUNDTABLE
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https://aiin.healthcare/node/129516

ML'S ROLE IN BUILDING CONFIDENCE AND VALUE IN BREAST IMAGING

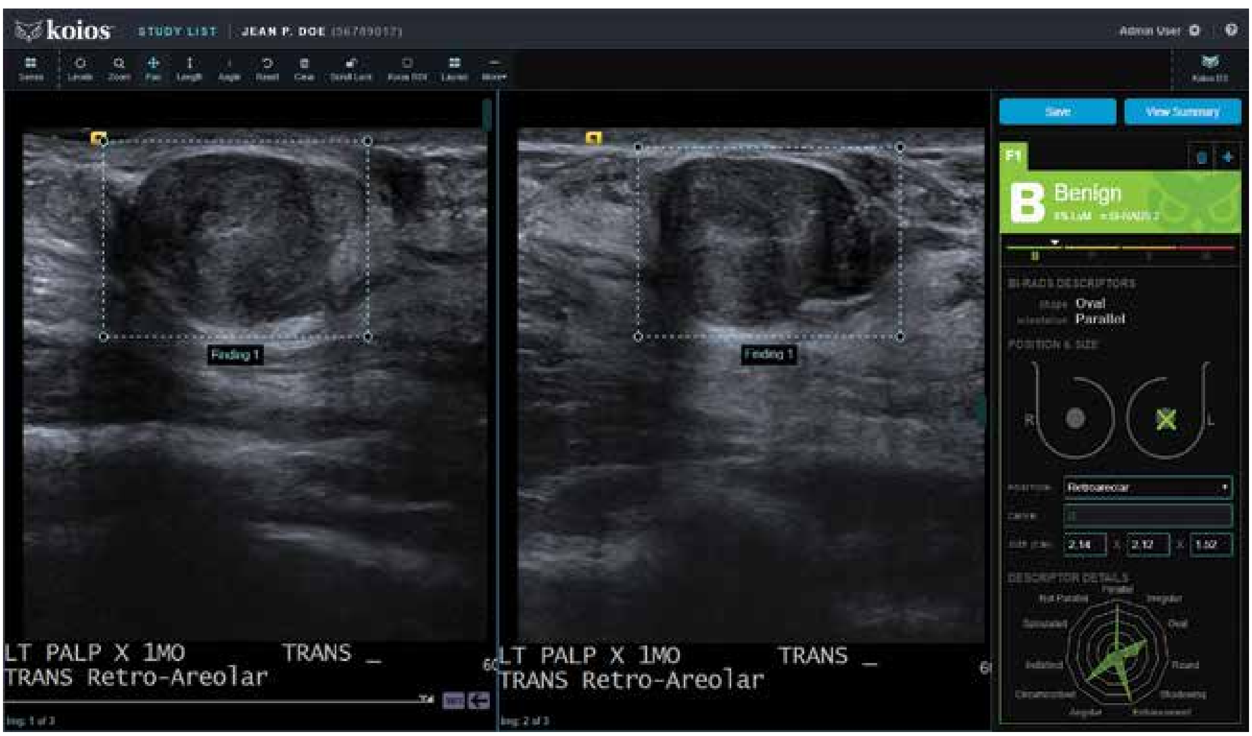
by Dave Pearson

Countless predictions have been made about artificial intelligence and machine learning changing imaging screening and diagnosis at the point of patient care—and clinical studies and experience are now proving it. Radiologists say the impact is real in improving diagnosis of cancers and quality of care, consistency among readers and reducing read times and unnecessary biopsies. One shining example targets the evaluation of breast ultrasound imaging.

Main Street Radiology in the New York City borough of Queens has been using machine learning software to analyze breast ultrasound images for screening and diagnosis for almost a year. The software, Koios DS for breast from Koios Medical, helps radiologists come to fast and accurate assessments of lesion characteristics and BI-RADS assessments. Hardware-agnostic, the software is compatible with most PACS.

"What's great about the software is that it allows for lesions that do not conform to an exact shape, such as an oval shape with one or two microlobulations," or bumps on the margins, explains Lai Yu, MD, co-section chief for breast imaging at 40-physician Main Street Radiology in Queens. "It allows us to have the confidence to make the call as to whether it's really something worrisome or not."

Viewing the image on a monitor, the radiologist drags an icon over the lesion of interest. The algorithm—which has been trained on hundreds of thousands of breast-lesion images—presents recommendations for lesion characteristics as well as a preliminary BI-RADS assessment. The tool is "very simple," says Yu, who is also a clinical assistant professor of radiology at Weill Cornell Medical College of Cornell University. "You look at it and right away you basically know how to use it.



> “What’s great about the software is that it allows for lesions that do not form an oval shape and may have just one or two microlobulations” [or bumps on the margins]. It allows us to have the confidence to make the call as to whether it’s really something worrisome.”
>
> Lai Yu, MD, Co-section Chief for Breast Imaging, Main Street Radiology and Clinical Assistant Professor of Radiology, Weill Cornell Medical College of Cornell University

Finding something easy to use is the key to what a good AI program is.”

Clinical studies prove the ML algorithm enhances diagnosis. A study in the *Journal of Digital Imaging* demonstrated an upcoming version of Koios DS for breast improved accuracy in breast cancer diagnosis for all radiologists across all levels of experience which is noteworthy because research shows physicians interpret the same cases differently, in up to one of every three cases. Sensitivity increased from a range of 92 to 97 percent to a range of 97 to 98 percent, and specificity increased from a range of 38 to 46 percent to a range of 45 to 52 percent. Benign biopsy rates were reduced 25 to 55 percent without a reduction in sensitivity.

A similar study published in 2017 in *Cancer Research* found a cancer identification rate of 100 percent with a 69 percent reduction in benign biopsies.

Yu took a closer look with her colleagues too, examining 100 cases sent to pathology. “It was sobering but made it very obvious to us that machine intelligence helps us as radiologists when we realized we could possibly have avoided 40 biopsies,” she says. “It can help us do a better job.”

CATCHING MORE CANCERS

For breast radiologists, getting better means catching more true cancers while reducing false positives and uncertain diagnoses. The latter can be both stressful and unnecessarily risky for patients, as receiving a diagnosis designated “tentative” often means undergoing a biopsy, returning (or staying) for more imaging—or both.

As for AI in healthcare as a whole, radiology is a natural early AI adopter. Medical images are a perfect fit for applying the same ML techniques that the Department of Defense uses to recognize human faces.

The front lines in the war against breast cancer are a perfect place to launch ML directly into patient care. According to the American Cancer Society, breast cancer is the second leading cause of cancer death in women behind lung cancer. Yet, thanks largely to early detection in screening due to heightened public awareness, death rates from female breast cancer dropped 39 percent from 1989 to 2015.

At Main Street Radiology, Yu says she uses ML in about 15 percent of the cases she reads. That may sound low, but it’s “quite impactful,” she says, “because those are the cases where you’re scratching your head. Having that second opinion for those kinds of cases makes a big difference.”

IT’S ALL ABOUT THE PATIENT

Yu also is focused on enhancing the patient experience—and increasing value in the patient care process. In fact, the literature is already beginning to bear this out.

In December 2018, two physicians from the University of California, Davis, published an analysis in the *American Journal of Roentgenology* concluding that AI technologies can, paradoxically, help radiologists demonstrate their value in the domain of the human touch.

“The promise of AI is its potential to release physicians from tasks that are better performed by automation,” wrote Radiologist Shadi Aminololama-Shakeri, MD, and Cardiologist Javier E. López, MD. “AI may enhance our diagnostic accuracy to the point that we are able to refocus on the art of the doctor-patient relationship.”

It is all about the patient, Yu agrees. “The yield of this may not be obvious until you realize that you’re recommending fewer biopsies and short-term follow-ups for findings that are benign,” she says. “Those things in and of themselves represent significant improvements in a practice. Administrators have to realize that your yield is not concrete. But having radiologists be so much more accurate—and better—in itself is worth it.” AI

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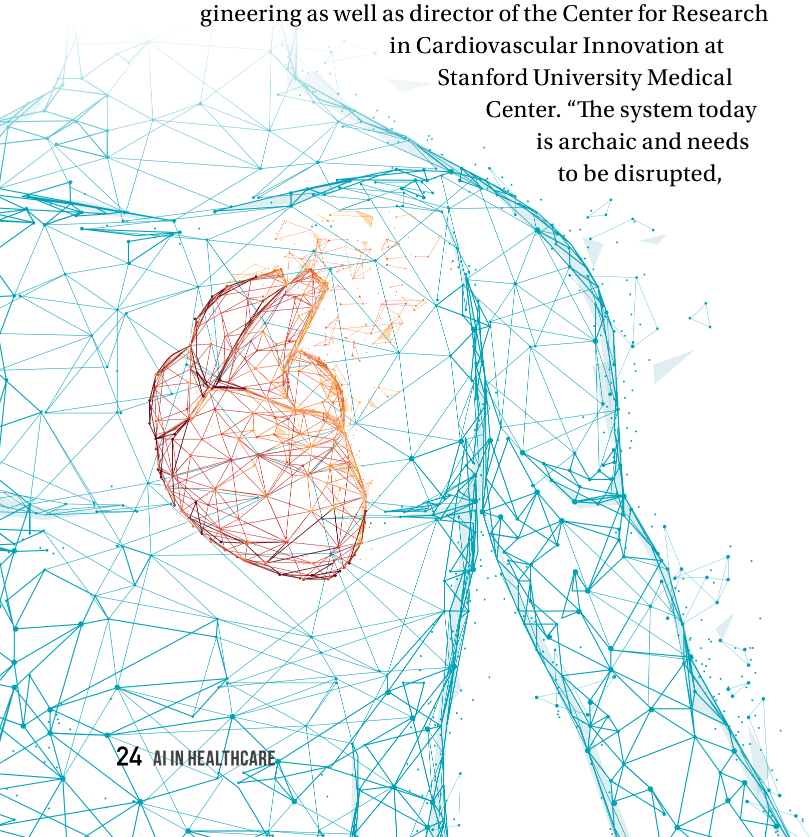
WILL 'SMART' SOLUTIONS REALLY TRANSFORM CARDIOLOGY?

by Randy Young

Smart technologies are often touted as the answer to some of cardiology's greatest challenges in patient care and practice. But where does hyperbole end and reality begin with artificial intelligence, machine learning and deep learning?

Even the most skeptical cardiologists can't help but feel the digital waves lapping at their feet. A "smart stent" with a special micro-sensor that acts as a miniature antenna to continuously monitor hemodynamic changes in the artery and transmit those data to an external reader. An AI-driven system that recently took 1.2 seconds to accurately interpret acute disease in brain CT scans, 150 times faster than humans. An algorithm that can forecast how long individual patients will remain in the hospital, their odds of being readmitted and the chances they will soon die.

"The unique changes that are occurring as information technology collides with healthcare technology are probably the most exciting thing I've seen in my 35 years in medicine," says Peter Fitzgerald, MD, PhD, who is deeply involved in that change as professor of medicine and engineering as well as director of the Center for Research in Cardiovascular Innovation at Stanford University Medical Center. "The system today is archaic and needs to be disrupted,



and it will be by the new players like Google and Apple and incredible IT folks who are coming on board."

John Rumsfeld, MD, PhD, is optimistically watching too. The chief innovation officer of the American College of Cardiology is among the first to cite the smorgasbord of opportunities that has the cardiovascular community excited. Wearables and smart phones have already become mainstream devices for monitoring patients' heart rate, blood pressure, breathing patterns, glucose levels and asthma, then uploading the data to the cloud for viewing by their physicians. Before too long, there could be an echocardiography smartphone app; wearables may measure heart rate variability; wristwatches will reliably predict atrial fibrillation; micro-radar sensors will detect heart and lung activity sans electrodes; and entire metabolic panels will be collected noninvasively (and remotely) through devices strapped to patients' arms or foreheads.

But for any of these applications to succeed, a much larger issue must be addressed: what to do with the torrent of data generated so it can be analyzed and interpreted in a way that benefits patients and physicians.

THE TRANSFORMATIVE ROLE OF AI

That's where AI and machine learning could be transformative. As Alfred Bove, MD, PhD, professor emeritus of medicine at Temple University School of Medicine in Philadelphia and a former ACC president, points out, physicians are already overwhelmed with terabyte-size data flows from their patients. "One way to handle it is to build logic systems that will collect the data, filter it and advise the doctor based on the best and most likely diagnoses," he says. "The next step would be to recommend a plan of action that could include medicines to be taken and images that are needed."

Fitzgerald, who's leading the technology charge at Stanford University, prefers to talk about the intelligence layer as "intelligence augmentation," or IA, a term he coined. He looks to an evolution where physicians are augmented

The inherent strength and promise of AI reside in deep phenotyping so you can understand each individual at an unprecedented level. But first you need to be able to assimilate and accurately interpret all that data, which is where deep learning and AI fit in so well.

Eric Topol, MD, Director of the Scripps Research Translational Institute and author of a forthcoming book, *Deep Medicine*

with information learned by population statistics and other algorithms. "So a 30-year-old [physician] who enters the cardiology field should be as smart a 60-year-old," he says.

For Eric Topol, MD, director of the Scripps Research Translational Institute and author of a forthcoming book, *Deep Medicine*, the inherent strength and promise of AI reside in "deep phenotyping so you can understand each individual at an unprecedented level," which means biologic and genomic along with the anatome and physiome. "But first you need to be able to assimilate and accurately interpret all that data, which is where deep learning and AI fit in so well."

IMAGING LEADING THE CHARGE

Imaging could be one of the earliest "intelligence-based" success stories. The reason, says Rumsfeld, is that the underlying data quality of images—against which machine learning algorithms are executed—is very high, allowing for complex pattern recognition and iterative learning. "I believe in the not-too-distant future AI will pre-read cardiac CTs, MRs, echoes and probably electrocardiographic tracings of all types," he predicts. "It won't replace the role of the cardiologist, who would still do an over-read. But it may be that while you can read one or two dozen studies in a day, that may double or triple with AI-supportive pre-reading."

Other experts in the field firmly believe that within the next decade virtually all imaging studies will be pre-analyzed through artificially intelligent machines before they ever get to the physician. AI will further enhance the review and diagnostic processes by data mining the patient's electronic health history for salient information, allowing for a more integrated clinical-imaging approach to patient care than is now possible.

RUMORS OF PHYSICIAN OBSOLESCENCE EXAGGERATED

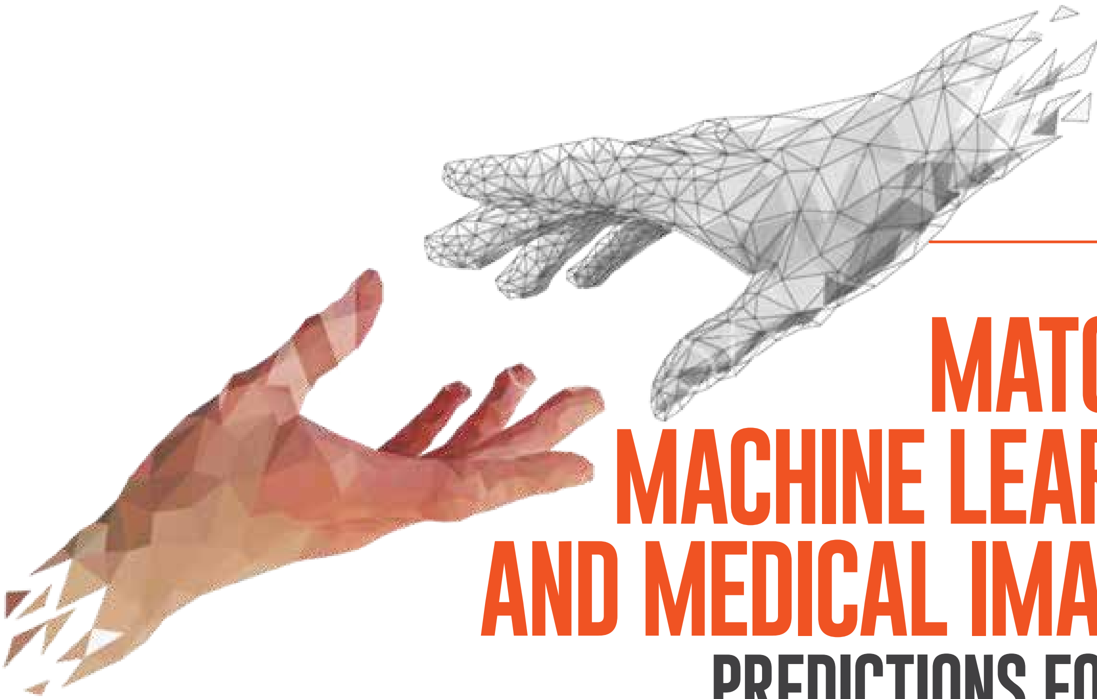
If technology is on the cusp of reconfiguring the healthcare landscape, where does that leave cardiologists? Will they become accessories to machines that can work around the clock without judgmental bias, fatigue of fear of burnout?

That's highly unlikely, says Bove, who is part of a sizable group that believes there will always be a role in healthcare for "low tech," that even the fanciest computational algorithm can't make a patient take his or her medicine. Physicians need to be the "arbiter of all the data," look at the big picture and how patient behavior integrates with everything else. "What will never become obsolete is the face-to-face personal encounter with the patient," he says. "That may ultimately be the most important thing we do as physicians to improve the outcomes of healthcare." AI

A longer version of this article can be found at CardiovascularBusiness.com

AI-powered imaging won't replace the role of the cardiologist, who would still do an over-read. But it may be that while you can read one or two dozen studies in a day, that may double or triple with AI-supportive pre-reading.

John Rumsfeld, MD, PhD, Chief Innovation Officer, American College of Cardiology



MATCHING MACHINE LEARNING AND MEDICAL IMAGING:

PREDICTIONS FOR 2019

Developments in vastly scalable IT infrastructure will soon increase the rate at which machine learning systems gain the capacity to transform the field of medical imaging across clinical, operational and business domains. Moreover, if the pace seems to be picking up, that's because data management on a massive scale has advanced exponentially over just the past several years.

Consider: Current graphics-processing unit (GPU) technology uses several thousand processing cores and delivers more than 100 teraflops of deep learning performance. GPUs are particularly well suited to image processing, which is a perfect first fit within healthcare for convolutional neural networks (CNNs). That's why CNNs are increasingly being applied to many medical imaging applications, most conspicuously (and least surprisingly) in radiology.

From a global view, it's clear that the acceleration of performance improvement in medical imaging AI systems—specifically as supported by advances in data storage and other aspects of IT infrastructure—is just one of numerous game-changing scenarios likely to unfold in the weeks, months and years just ahead.

All are worth considering in some detail. Possibly none would be considered especially noteworthy outside of technology circles if not for one salient point: The medical imaging industry is still in a very early phase of its adoption of AI-fueled innovation. Whatever specific applications and new wrinkles emerge next will disrupt all aspects of the profession. That's why now is the time for healthcare providers to begin constructing a machine learning strategy—and to leave room in it for adjustments to unforeseeable developments as well as expected end points.

Before charting a path to there from here, it will be helpful to consider some of the aforementioned near-future scenarios and what to expect as each unfolds.

- **The market for machine learning is surging, fueled by a need to improve accuracy and efficiency.** So far, the use of machine learning in routine diagnostic imaging has been limited. That is poised to change dramatically in the coming years as CNNs and other deep learning techniques proliferate. Forces driving the market for AI-based software that analyzes medical images include increasing radiologist workloads, errors and discrepancies in radiologists' image interpretations, and the increasing use of AI for nonclinical applications such as workflow prioritization, quality assurance and overall practice management.
- **Machine learning will improve the care experience for radiology patients.** From initial scheduling of the imaging examination to final diagnosis and follow-up appointments—and every step along the way, including image acquisition, findings reporting and treatment planning—AI and machine learning will facilitate smarter, more streamlined processes that help achieve better outcomes while also adding to overall patient satisfaction. For providers this will translate to operational efficiencies and substantial cost savings.
- **Research and innovation will yield new and compelling use cases.** As of now the radiological subspecialty furthest along with AI is screening and diagnostic breast care. This is so because the field has been using pre-AI computer-assisted detection (CAD) techniques to find cancers for many years, and machine learning has been a natural next step. However, use cases for advanced AI-aided image analysis are well in development for diseases of the lungs, brain, heart, musculoskeletal structures and all internal organs.
- **Technology vendors will offer new medical imaging AI products as quickly as academic research centers**

can test and prove new algorithms. Studies on machine learning have been expanding rapidly in recent years in peer-reviewed medical journals. Accordingly, established technology vendors are collaborating with the researchers at a heightened pace, seeking to remain competitive in an AI-driven healthcare market. To that end, strategic distribution and technology licensing partnerships are increasing and the first online AI marketplaces are already open for business.

- **No 'ology' will be left behind.** Radiology isn't alone in its readiness to adopt machine learning advances for various use cases. Ophthalmology and oncology are gaining ground, while dermatology, surgery and pathology are all in the game. In fact, pathology is something of a sister 'ology to radiology, since both depend on ultrafine image interpretation of anatomical systems. Over time, quantitative imaging biomarkers extracted from diagnostic imaging (radiomics) will be combined with quantitative biomarkers of pathophysiology and other sources of patient data for better prognostic prediction of disease progression. This will enable improved treatment planning and better patient outcomes.
- **Health providers will leverage data hubs to unlock the value of their data.** The push for more integrated care across U.S. healthcare is combining with the rise of machine learning to demand optimized data interoperability. This is best achieved via centralized platforms on which healthcare provider organizations can build a base for all diagnostic medicine and care management. Forward-thinking providers are moving to enterprise data hubs, which will increasingly facilitate access and interoperability of both structured and unstructured data across multiple clinical applications. With such a broad base of data to draw from and train on, machine learning algorithms will be able to produce ever richer and deeper insights.

Advances in AI-ready IT infrastructure represents the cornerstones on which modern healthcare will build a constantly learning system of continuous quality improvement across clinical, operational and business domains. Along with the aforementioned GPU servers, all-flash storage is gaining acceptance over legacy hard disk drives in health IT infrastructure due to the lower read/write latency, higher throughput performance and maximized scalability. As these kinds of infrastructure improvements continue to strengthen the architectures undergirding AI-aided systems in healthcare, watch for machine learning to continue improving care quality and patient experience even as it increases efficiencies and drives down healthcare costs.

Adapted from a white paper by Simon Harris, principal analyst with Signify Research. To download the full document, "What's New for Machine Learning in Medical Imaging: Predictions for 2019 and Beyond," click here: https://www.purestorage.com/resources/type-a/whats-next-for-machine-learning-in-healthcare-imaging.html.

TOP 7 PREDICTIONS

- The market for machine learning in diagnostic imaging will top $2 billion by 2023.
- Machine learning will improve the radiology patient experience at every step.
- New and compelling use-cases will continue to emerge.
- Medical imaging AI will transition from academic research to commercialization.
- Machine learning will benefit all medical imaging 'ologies.
- Health providers will leverage data hubs to unlock the value of their data.
- Developments in IT infrastructure will accelerate the performance of medical imaging AI systems.

Source: Signify Research